CRETACIFILIX FUNGIFORMIS GEN. AND SP. NOV., AN EUPOLYPOD FERN (POLYPODIALES) IN EARLY CRETACEOUS BURMESE AMBER

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ABSTRACT

An eupolypod fern, **Cretacifilix fungiformis** gen. & sp. nov. (Polypodiales) is described from four partial, fertile leaf blades in a piece of Early Cretaceous Burmese amber. Diagnostic characters are: oval, thick-walled sporangia with vertical, short annuli not extending more than half the circumference of the sporangia, deeply embossed, circular sori with brown, multicellular, round to reniform, persistant indusia attached at the sinus and ruggose-tuberculate, oval, monolete spores. This discovery shows that eupolypod ferns and angiosperms were evolving concurrently at the Burmese amber site in the Early Cretaceous.

Key Words: amber, Myanmar, Early Cretaceous, eupolypod fern

RESUMEN

Se describe un helecho eupolypodioide, **Cretacifilix fungiformis** gen. & sp. nov. (Polypodiales) a partir de cuatro partes de hojas fértiles, de una pieza de ámbar del Cretácico temprano de Birmania. Los caracteres diagnósticos son: esporangios ovales con pared gruesa con anillos verticales cortos que no se extienden más de media circunferencia de los esporangios, soros circulares profundamente labrados, con indusios persistentes marrones, multicelulares, de redondos a reniformes, unidos en el seno, y esporas monoletas, ovales, rugoso-tuberculadas. Este descubrimiento muestra que los helechos eupolypodioides y las angiospermas evolucionaron simultáneamente en el Cretácico temprano en el lugar del ámbar birmano.

INTRODUCTION

Amber from Burma (Myanmar), which has been known for centuries, contains a variety of insect and plant fossils (Poinar et al. 2006). A recent discovery revealed the remains of four fertile pinnules of an eupolypod fern in a piece of Burmese amber. Fern remains are rare in amber and only three species have been described. They are *Alethopteris serrata* Caspary (1881) and *Pecopteris humboldtiana* Göppert and Berendt (1845) from Eocene Baltic amber (both of the above extinct genera had been established previously for Carboniferous ferns) and *Grammitis succinea* Gómez (1982) in Miocene-Oligocene Dominican amber.

The present study describes the Burmese amber fern using characters associated with the sori, indusia, sporangia and spores.

MATERIALS AND METHODS

The amber was derived from a mine first excavated in 2001, in the Hukawng Valley, southwest of Maingkhwan in the state of Kachin (26°20'N, 96°36'E) in Burma (Myanmar). This new amber site, known as the Noije Bum 2001 Summit Site, was assigned to the Upper Albian of the Early Cretaceous on the basis of paleontological evidence (Cruickshank & Ko 2003). Nuclear magnetic resonance (NMR) spectra and the presence of araucaroid wood fibers in amber samples from the Noije Bum 2001 Summit site indicate an araucarian (probably *Agathis*) tree source for the amber (Poinar et al. 2007).

The single piece of amber containing the fern remains (Fig. 1) was roughly rectangular in shape, measuring 12 mm long, 6 mm wide and 1 mm in depth. Observations, drawings, and photographs were made with a Nikon SMZ-10 R stereoscopic microscope and Nikon Optiphot compound microscope (with magnifications up to 700×). It is not possible to determine whether the blades were pinnate, bipinnate or tripinnate. The lengths of the four fertile pinnules in the amber are: pinnule A, 3 mm; pinnule B, 4.9 mm; pinnule C, 5.2 mm and pinnule D, 2.4 mm. Each pinnule contains one or more sori on their abaxial surfaces (Figs. 1, 5).

DESCRIPTION

Cretacifilix G.O. Poinar & R. Buckley, gen. nov. Type Species: *Cretacifilix fungiformis* G.O. Poinar & R. Buckley (Polypodiales).

Diagnosis.—Rhizome, stipe, rachis and costa unknown. Fronds of unknown length; pinnules lobed, mostly glabrous with few scattered unicellular hairs on surface and margins; veins free, not reaching margins, not ending in hydathodes; sori medial, orientated mostly in alternate positions in two rows, with mostly one, but sometime two sori bone on single pinnule lobe, deeply embossed, resulting adaxial pustules at ends of veins; sori covered by brown, thick, glabrous, multicellular, round to reniform, persistant indusia with stalk attached by inner end of sinus with distal and lateral openings; some indusia bent backwards, revealing ribbed stalks; sporangial stalks composed of 1–3 rows of cells; sporangia oval, thick-walled, walls composed of small, narrow, elongate cells; annulus vertical, short, broad, not extending more than half circumference of sporangia, with less than 10 thick walled cells; spores small, oval, ruggose-tuberculate, monolete.

Cretacifilix fungiformis G.O. Poinar & R. Buckley, sp. nov. (**Figs. 1–5**). Type: MYANMAR. Kachin: Noije Bum 2001 Summit Site in the Hukawng Valley, SW of Maingkhwan in the state of Kachin (26°20'N, 96°36'E), 2005–2007, *collector unknown* (holotype: catalogue # B-11, amber collection of Deniz Erin in Istanbul 34744, Turkey). This collection is available for study. Further contact information can be obtained from Ron Buckley at ronbuckley@fuse.net.

Description.—**Four fertile pinnules:** indusia (N = 22) opening outward, 416(360–504) µm in width, 233 µm in length; indusial stalk 142(104–208) µm wide, width of cap, 183(90–436) µm; cells of indusia thick walled, many filled with discrete, minute bacilliform bodies ranging from 3–4 µm in length and 1–2 µm in width; stalk of indusia often ribbed (possibly from desiccation); sporangia oval-shaped; capsule walls composed of thick walled, narrow, elongate cells; sporangia (N = 10), 158(140–189) µm in length, 115(81–150) µm in width; annulus short, containing less than 10 thick-walled cells and extending no more than half circumference of sporangia; length annulus (N = 5), 53(24–72) µm; width annulus (N = 3), 53(24– 72); spores (N = 8) monolete, oval, 21(16–29) µm long and 14(11–20) µm wide, surface ruggose-tuberculate, perispore not evident; hairs on margins and veins of pinnules range from 28–195 µm in length.

Etymology.—*Cretacifilix* is derived from the Latin Cretaceus for "chalky" indicating the Cretaceous period and from the Latin "filix" for fern: *fungiformis* is derived from the Latin "fungi" for mushroom and the Latin "forma" for shape in reference to the resemblance of the indusia to fruiting bodies of chanterelles and some shelf-like mushrooms.

DISCUSSION

Since the vegetative structures and habit of *Cretafilix* are unknown, systematic placement is based on the reproductive characters. The presence of a vertical annulus that partially encircles the spore case (Figs. 2, 5) places the fossil in the Eupolypods clade of the Polypodiales (Schneider et al. 2004; Smith et al. 2006). It was not possible to place *Cretacifilix* in an extant family because of its unique combination of characters. Surficial sori with reniform indusia are characters of the families Dryopteridaceae and Woodsiaceae (and are also known from some members of the Thelypteridaceae, Tectariaceae and Lomariopsidaceae) as defined by Smith et al. (2006). However members of the Dryopteridaceae and Woodsiaceae possess reniform, trilete spores and the spores of *Cretacifilix* are oval and monolete. Also the indusia of these families are usually not multicellular and thick as with *Cretacifilix* (Bower 1928; Sledge 1973).

Another character of *Cretacifilix* not found in the Dryopteridaceae or Woodsiaceae is the deeply embossed sori (Plate 2). This character closely resembles that found in the North American *Pleopeltis polypodioides* (L.) E.G. Andrews & Windham of the Polypodiaceae (Cobb et al. 2005). This species, commonly known as the resurrection fern, has the characteristic of curling up and appearing dead during periods of drought, but then recovering when conditions are favorable. If embossed sori are associated with survival during periods of aridity, it would suggest that *Cretacifilix* might have been subjected to similar climatic conditions. The resurrection fern occurs on tree branches (Cobb et al. 2005), which is a likely habitat for *Cretacifilix* and would explain how fronds of the fossil made contact with resin on the trunk of the araucaroid tree.

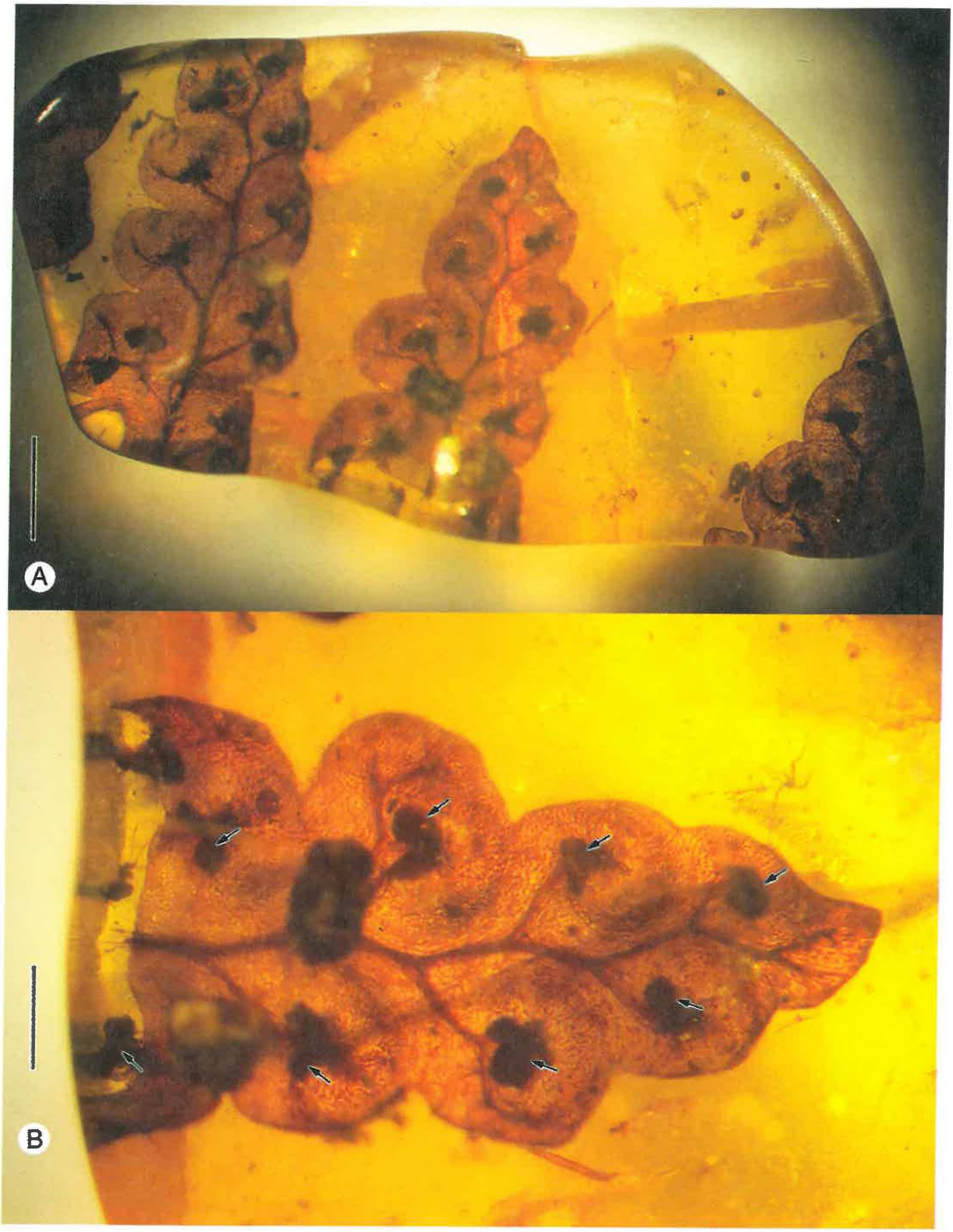

FIG. 1. *Cretacifilix fungiformis*. **A.** Burmese amber piece with four partial pinnules (A,B,C,D, from left to right). Scale Bar = 1.2 mm. **B.** Pinnule B. Arrows show brown, persistent indusia. Scale Bar = 0.6 mm.

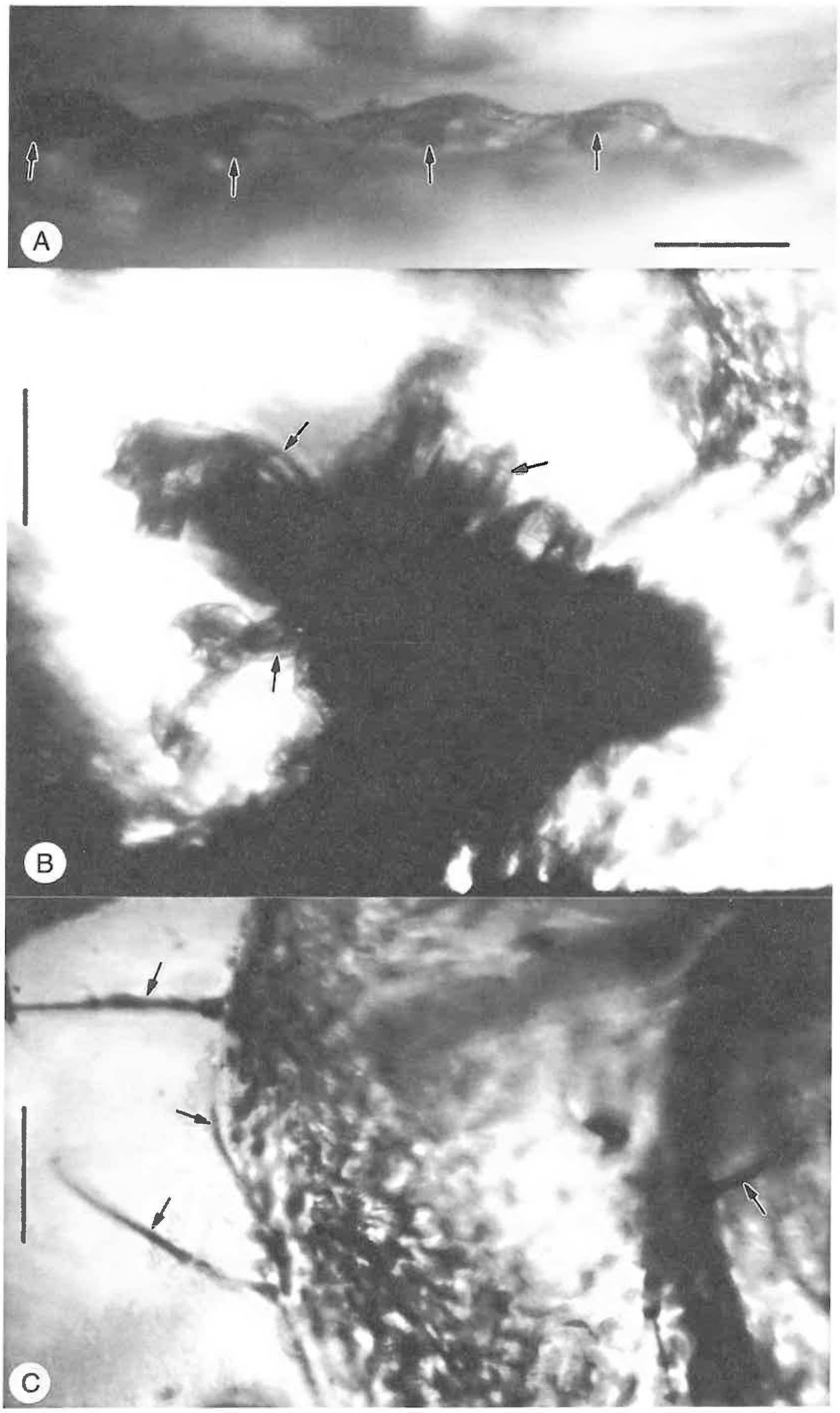

FIG. 2. *Cretacifilix fungiformis*. **A.** Pustles on the adaxial surface of pinnule **B.** Arrows show sori on abaxial surface. Scale Bar = 1 mm. **B.** Indusium with remains of sporangial stalks (arrows) protruding from edges. Scale Bar = 110 µm. **C.** Hairs (arrows) on margins and vein of pinnule. Scale Bar = 62 µm.

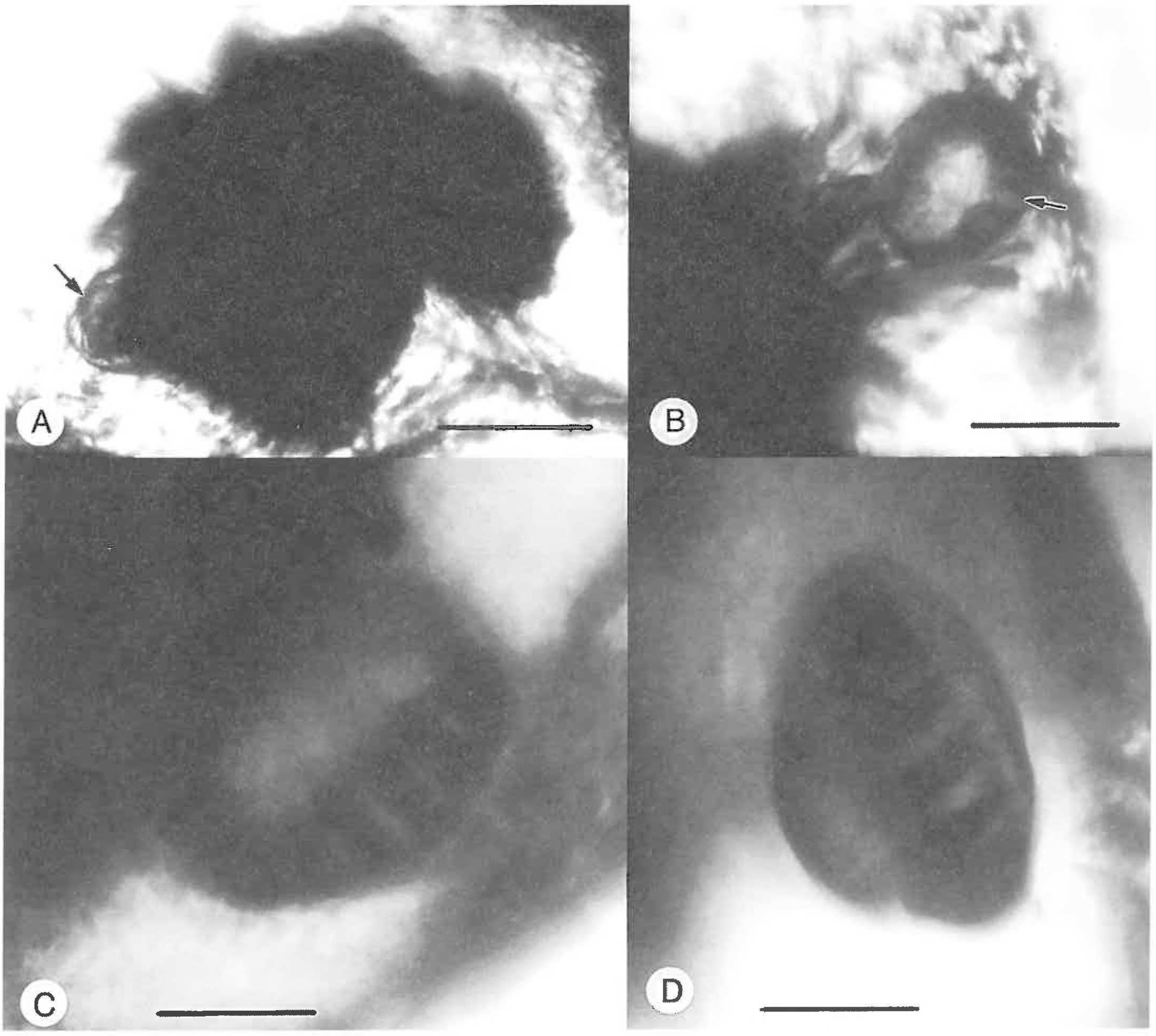

FIG. 3. *Cretacifilix fungiformis*. **A. Indusium with partly protruding sporangia (arrow). Scale Bar = 60 µm. B. Sporangium with opening on side of capsular wall. Arrow shows annulus. Scale Bar = 126 µm. C. Lateral view of sporangium with annulus. Scale Bar = 73 µm. D. Vertical view of sporangium with annulus. Scale Bar = 53 µm.**

Asian dryopterid species with similar sori are *Arachniods standishii* (Moore) Ohwi, *Dryopteris lacera* (Thumb.) O. Kuntze and *Dry opteris chinensis* (Bak.) Koidz. However, in the former two species, the veins extend to the tips of the pinnules and the sori are either on the veins or in opposite rows, and in the latter species, the annulus has 17 thick- walled cells and extends more than half way around the circumference of the sporangium (Lee 1999).

The annulus of extant leptosporangiate ferns extends at least two thirds around the circumference of the sporangial capsule (Moran 2004). The short annuli, thick, narrow cell walls of the sporangial capsules and small, oval spores appear to be unique features of *Cretacifilix*. The small bacilliform bodies in the indusial cells could indicate a symbiotic association. No reports of similar bodies in the indusial cells of extant ferns could be found.

The presence of an eupolypod fern in the Early Cretaceous supports other records of fossil Polypodiales ferns from the same period (Deng 2002). Based on molecular studies, eupolypod subclades are thought to have diversified in the Late Cretaceous (Schneider et al. 2004), but it is obvious that they were already present in the Early Cretaceous and evolving concurrently with early angiosperms, several of which have

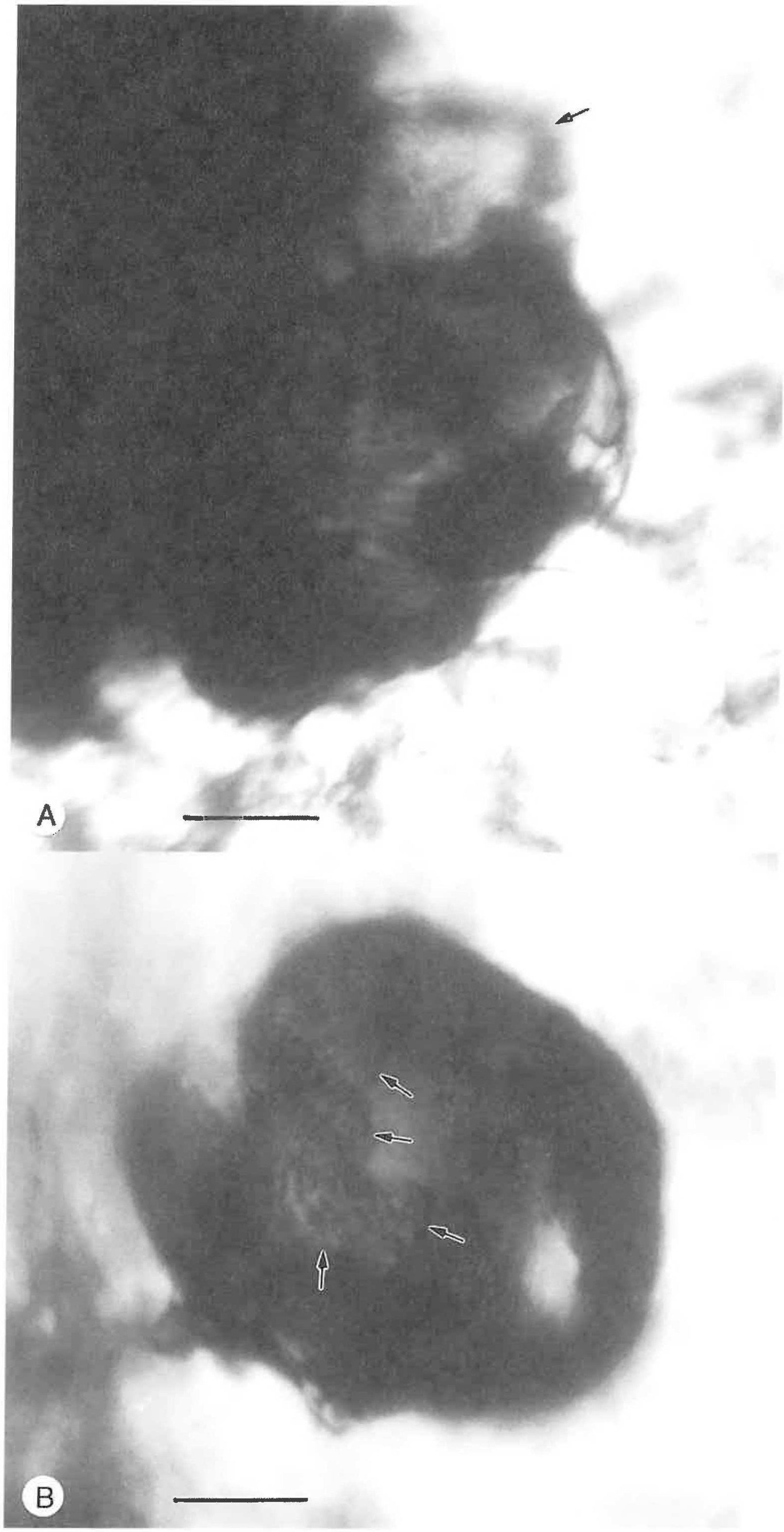

FIG. 4. *Cretacifilix fungiformis*. **A.** Sporangium wall composed of narrow, elongate cells. Arrow indicates stalk. Scale Bar = 37 µm. **B.** Sporangium with a portion of wall removed, revealing four spores (arrows). Scale Bar = 25 µm.

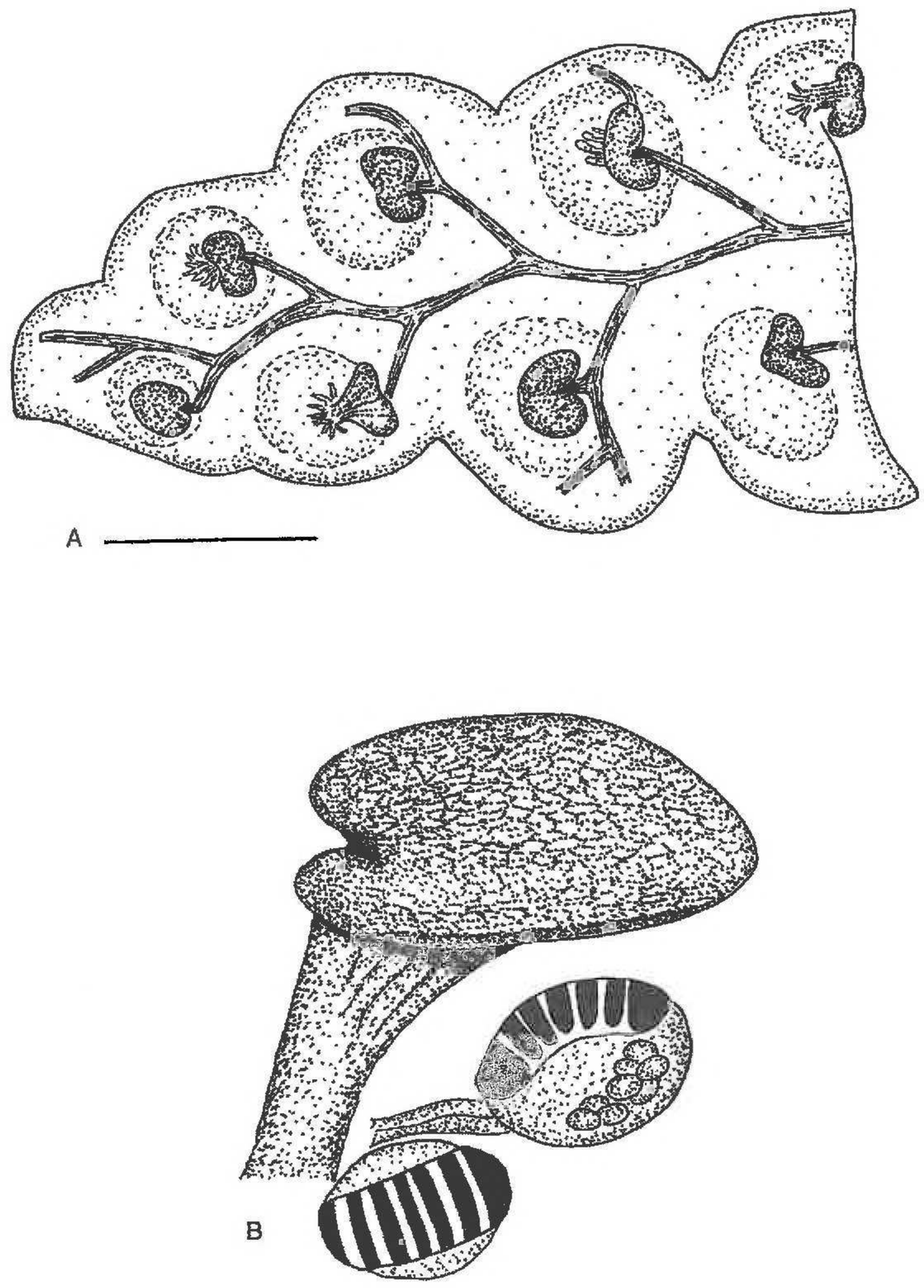

FIG. 5. *Cretacifilix fungiformis*. A. Pinnule B showing veins and indusia. Scale Bar = 0.6 mm. B. Partial reconstruction of stalked indusium and two sporangia, one of which contains 8 spores (proportions maintained).

been recovered from the same Burmese amber fossil site (Poinar 2004; Poinar & Chambers 2005; Poinar et al. 2007).

All evidence indicates that the Burmese amber forest was a tropical-subtropical rainforest with many floral characteristics of the Waipoua kauri forest in Northern New Zealand. The Waipoua forest is the only virgin *Agathis* forest in the world today and comprises a mixed dense ecosystem of flowering plants, ferns, lycopods and moss on 90 sq km of land. Of the 241 plants that have been recorded, 178 species are seed bearing and 63 are ferns or lycopods (McGregor 1948).

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